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THE ERRORS OF CUTANEOUS LOCALIZATION AND THE EFFECT OF PRACTICE ON THE LOCALIZING MOVEMENT IN CHILDREN AND ADULTS*

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THE PROBLEM

Localizing a punctate stimulation upon the skin immediately opens a major issue in psychological theory. Until comparatively recent years there was no need to seek beyond the local sign doctrine of Lotze and Müller's hypothesis of the specific energies of afferent conductors to account adequately for localization. Peterson (5) has presented a critical review of these doctrines and proposes in place of them the view that localization is "a special aspect of the general field of learning." Meyer (4) had proposed as early as 1911 a description of the process in neuromuscular terms of the same general type. Koffka (3) classes the haptic space discriminations as perceptions which eventuate from a process of figure-ground structuring and denies that they are generally accounted for by any type of "experience" theory of learning.

Peterson (5) holds that there is "little doubt that the early practice afforded an infant in adjustment to local stimuli . . . . yields very great results in a few months; so it is not surprising to find the young child's orientation to bodily stimuli so accurate as to lead many observers to the conclusion that its basis is mainly innate" (p. 232). A survey of the experimental literature on this point yielded very little direct evidence. The experiments described in this paper were made to throw some light on the questions of the relationship of the magnitude and direction of the errors of localization upon the skin by children as compared to that of adults and to determine the effect of practice on the localizing movement.

If localizing is a species of habit or a learned act, then, in general,

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the accuracy of localizing should increase with practice. And, if practice in localizing is a function related to age (i.e., increased opportunities for localizing), we should find the magnitude of error some inverse function of age. Thus adults should localize more accurately than children, unless with increasing age or practice something analogous to experimental extinction may take place. If the change from childhood to adulthood brings with it a replacement of a prime localizing mechanism (kinaesthetic-tactual) by a derived or secondary mechanism (distance receptor), then we should guess that, in general, children should localize more accurately than adults. In such a case the logic of comparing directly the experimentally determined errors of the two age groups would be highly questionable. And, as indicated by Peterson, the superiority of children to adults need not lead to the conclusion that "its basis is mainly innate." Nor should such a fact be admissable as evidence in support of the case against the "experience" theory of such "perceptions."

Ponzo (6) studied the accuracy of localizing on 25 areas on the body. He concludes that errors of localizing differ in size and direction in various areas, but are fairly constant for a given area. He holds that there is no stable relation between threshold value and accuracy of localization nor decrease in accuracy with lower intensities of stimulation. All his subjects were adults. Most of the errors as well as the mean errors were in the longitudinal direction.

In another investigation this same writer (7) studied the effect of practice in localizing with adults. Ten spots on the volar forearm were stimulated. Ten sittings on 10 successive days led him to conclude that practice has no effect on the amount or direction of the error. In this respect he claims localization differs from the two-point limen. In a similar way Franz (1) concluded that there were no practice effects by five *S*'s in localizing upon 60 points over the entire body surface. In all of the abundant literature on haptics no work was found in which children's localizations were compared with those of adults (2, p. 228).[1] In addition to the usual findings

[1]One exception to the above statement is found in (2), which summarizes the early work covering the period from E. H. Weber (1852) to the Leipzig experiments (c. 1898). In the section pp. 90-142 there is a brief reference to Czermak's comparison of two-point limen and localization of children and adults, both blind and seeing, with the general statement that the blind are superior in both things to the seeing. The *Psychological Index* lists 105 articles and summaries covering the period from 1894-1928. No comparisons of the type reported in this paper were found in this literature. Czermak's work is described in *Sitz.-Ber. d. Wien. Akad.*, 1855, **18**, 577-600.

regarding the superiority of transverse to longitudinal localizations, relation to curvature, etc., the trend seems to incline toward a denial of the susceptibility of localizing movements to improvement through practice.

METHOD

Seven adults, ranging in age from 18 to 65 years, and four children, from 8 to 11 years, served as subjects in our experiments. In all 6,720 localizations were made by these subjects, 30 per day on each of two skin areas. The sittings were distributed over a period of from 7 to as many as 32 days for various subjects.

At this point I wish to express my obligation to Mr. Charles E. Wu, graduate student in the Department, who served as the experimenter throughout these experiments; also to the subjects for giving generously of their time.

Two areas 30 millimeters square were selected. One of these was upon the back of the non-preferential hand and the other upon the flat surface of the volar forearm midway between elbow and wrist. These areas were imprinted upon the skin daily by means of a rubber stamp and the relocations made approximate from four small point picric acid stains. Thirty ink spots were distributed evenly throughout the millimeter squares. These spots became the points stimulated. At each sitting *E* stimulated each spot by a relatively uniform pressure and for a uniform duration of approximately a half second. *S* made his localization immediately upon removal of the stimulator by moving his preferential hand through about 15 inches at as uniform a speed as possible and indicated without "hunting" the stimulated spot by means of a pointed wooden surgical applicator. Mr. Wu was careful to train his subjects so as to secure uniformity in the manner of making the localizing movement, particularly in the matter of the range and speed of movement and the elimination of "hunting," which the preliminary work had shown us had great effect upon the magnitude of the errors. Both the magnitude and direction of each localizing error were recorded by *E*, who also jotted in the protocols any commentaries volunteered by the *S*'s. Each *S* remained blindfolded throughout the sitting and worked without knowledge until the end of the sitting, whereupon he was permitted to discuss with the *E* the day's observations. Each point stimulated was regarded as located upon two intersecting lines dividing the whole area into four imaginary quadrants. Thus the

total area in each imaginary quadrant varied from stimulation to stimulation. The direction (fingerward, wristward, distal, or proximal) and magnitude of the errors were recorded in each quadrant. The same procedure was employed for the volar forearm.

Results

The Accuracy of the Localizations. Tables 1 and 2 present the means and mean deviations in millimeters for each day of the localizations of the adult subjects on hand and volar forearm. Tables 3 and 4 present the same data for the children.

TABLE 1

Cutaneous Localization: Back of Hand

Mean Daily Error in Millimeters—30 Localizations per Day

Adults

Subject	Age	Days 1	2	3	4	5	6	7	8	9	10
Mr. C	18	19.8	14.2	13.5	10.1	12.4	10.3	10.5	9.8	8.9	6.8
Mr. N	19	15.1	14.0	16.7	9.6	13.4	11.9	11.2	9.0	11.6	9.8
Mrs. N	20	11.7	8.1	9.5	11.5	9.7	9.1	9.1	9.1	9.1	8.5
Miss R	20	10.8	12.0	6.6	8.3	9.3	8.1				
Mr. M	20	13.6	14.2	13.8	10.9	11.7	14.5	13.7	9.9		
Mr. L	23	5.9	6.6	5.5	5.9	4.7	5.3	6.1	5.8	5.5	6.4
Mrs. J	65	9.0	10.4	11.1	14.2	11.6	10.7	14.1			
Means		12.2	11.3	10.9	10.0	10.4	9.9	10.8	8.7	8.8	7.9
Mean deviations		3.3	2.2	3.2	1.8	2.1	2.4	2.2	1.4	1.6	1.3

TABLE 2

Cutaneous Localization: Volar Forearm

Mean Daily Error in Millimeters—30 Localizations per Day

Adults

Subject	Age	Days 1	2	3	4	5	6	7	8
Mr. C.	18	13.4	15.9	14.1	9.5	16.0	16.1	9.6	6.7
Mr. N	19	15.1	13.5	17.7	15.6	16.3	19.6	11.0	10.7
Mrs. N	20								
Miss R	20	22.2	15.2	13.7	13.1	16.7	10.9		
Mr. M	20	16.0	16.2	18.2	20.2	12.3	14.9	16.1	16.6
Mr. L	23	12.0	18.0	13.5	15.6	18.2	12.4	16.6	13.2
Mrs. J	65	11.8	11.5	10.9	13.4	11.1	13.2	12.0	
Means		15.0	15.0	14.7	14.5	15.1	14.5	13.0	11.8
Mean deviations		2.6	1.7	2.1	2.5	2.2	2.3	2.6	3.1

TABLE 3

CUTANEOUS LOCALIZATION: BACK OF HAND

Mean Daily Error in Millimeters—30 Localizations per Day

CHILDREN

Subject	Age	Days 1	2	3	4	5	6	7	8	9
Alice	8	9.7	8.0	7.1	4.0	3.8	3.6	3.0		
Jane	10	10.3	5.3	6.2	4.3	3.6	3.5	2.0		
Dorothy	10	3.7	2.3	2.4	1.6	1.2	1.5	0.8	0.9	0.8
Martha	11	17.9	6.6	4.7	7.1	5.4	5.2	4.6		
Means		10.4	5.5	5.0	4.2	3.5	3.4	2.6		
Mean deviations		3.7	1.7	1.5	1.4	1.1	1.0	1.2		

TABLE 4

CUTANEOUS LOCALIZATION: VOLAR FOREARM

Mean Daily Error in Millimeters—30 Localizations per Day

CHILDREN

Subject	Age	Days 1	2	3	4	5	6	7	8	9
Alice	8	9.4	6.8	7.0	4.9	3.1	4.8	3.2		
Jane	10	8.1	4.5	5.3	6.5	5.9	4.3	4.1		
Dorothy	10	4.8	4.1	2.4	2.1	1.5	1.6	1.3	0.9	1.1
Martha	11	8.8	2.0	4.2	5.9	4.0	3.8	3.4		
Means		7.7	4.3	4.7	4.8	3.6	3.6	3.0		
Mean deviations		1.3	1.3	1.4	1.4	1.3	1.0	0.8		

Table 1 is read as follows: Subject C on his first sitting showed an average error of 19.8 millimeters in making 30 localizations on the area on the back of his hand. On the second day his average error was 14.2 millimeters, etc. The mean error of all adult subjects on the first day was 12.2 mm., with a mean deviation of 3.3 mm., etc.

Figure 1 presents a graphic summary of the means for each day for each group.

From an examination of the tables and the curves we may conclude:

1) Comparatively large practice effects are shown both in the case of the children and the adults, both on hand and forearm.

2) The children are not only more accurate initially but show much greater and more rapid decrement in error than do the adults.

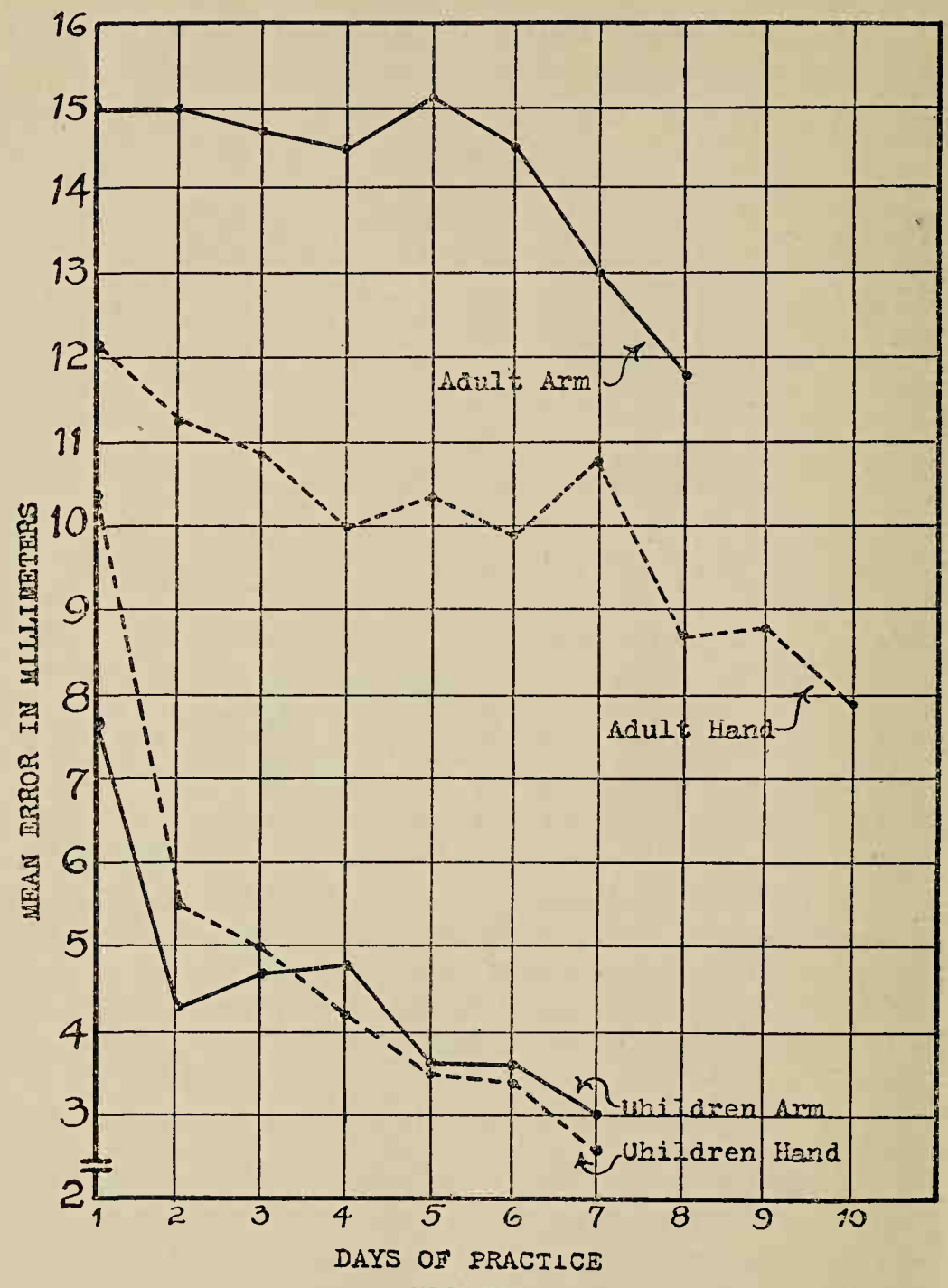

FIGURE 1

MEAN DAILY ERRORS OF LOCALIZATION ON HAND AND VOLAR FOREARM BY ADULTS AND CHILDREN

3) The ratios of the differences to the mean deviations of the differences between the two groups computed from the formula

$$\frac{D}{MD_d} = \frac{D}{\sqrt{\frac{(MD_{dist\ A})^2}{N_A} + \frac{(MD_{dist\ B})^2}{N_B}}}$$

are as follows. For the hand on the first day the ratio is 0.81. The chances are therefore 74 in 100 that this difference is a valid difference. For the forearm on the first day the ratio is 5.9, or 99.9+ chances in 100 for the validity of the difference. For the hand on the seventh day the ratio is 8.04, or practical certainty, and for the forearm seventh day it is 8.1.

4) The mean error for adults on forearm on the eighth day of practice is slightly less than the mean error for the adult hand on the first day.

5) The differences between hand and forearm in the adults are significantly greater than they are in the case of children throughout the first eight days of practice.

6) The adult curve for the hand shows a rather progressive error decrement from day to day. In contrast the adult forearm shows no improvement during the first five of the eight days of practice, after which it shows an abrupt drop.

7) It is significant that during the first two days the children localize more accurately upon the forearm than upon the hand, in contrast with the opposite state of affairs with the adults.

8) Children show marked superiority to adults in localizing both initially and after practice.

Direction of the Errors of Localization. The following tables present an analysis of the mean number of localizations per sitting in each quadrant. It should be noted in reading the tables that the rows and columns do not always total 30, since all localizations falling on the meridians were tabulated as zero in direction and hence are not listed in any of the designated quadrants. Also in Table 5 Subject Dorothy made 34 hand localizations instead of 30. These tables are presented in order that we may gain some rough estimate of the trends of direction of the errors, and to ascertain the differences in direction, if any, between the two groups of subjects.

TABLE 5

DIRECTION OF LOCALIZING ERRORS—CHILDREN
HAND

Subject	Age	Sittings	Mean localizations per sitting Wrist	Finger	Distal	Proximal
Alice	8	7	10.4	18.7	14.1	15.0
Jane	10	7	13.8	14.8	8.0	20.7
Dorothy	10	12	11.5	22.5	12.9	21.1
Martha	11	7	16.7	12.7	22.1	7.2
	Mean		13.1	17.1	14.2	16.0

TABLE 6

DIRECTION OF LOCALIZING ERRORS—CHILDREN
ARM

Subject	Age	Sittings	Mean localizations per sitting Elbow	Wrist	Distal	Proximal
Alice	8	7	10.2	18.0	14.8	13.4
Jane	10	7	12.4	15.0	15.2	12.2
Dorothy	10	12	4.5	22.4	13.8	13.1
Martha	11	7	13.5	14.1	20.1	7.5
	Mean		10.1	17.4	15.9	11.5

TABLE 7

DIRECTION OF LOCALIZING ERRORS—ADULTS
HAND

Subject	Age	Sittings	Mean localizations per sitting Wrist	Finger	Distal	Proximal
Mr. C.	18	16	14.9	15.0	16.8	13.0
Mr. N	19	10	22.3	7.6	11.8	18.1
Mrs. N	20	10	18.2	11.6	22.2	7.6
Miss R	20	6	8.6	20.8	19.3	10.1
Mr. M	20	8	21.8	8.1	13.0	17.0
Mr. L*	23	22	19.1	20.8	25.5	14.4
Mrs. J	65	11	21.1	8.8	12.2	17.7
	Mean		18.0	13.2	17.2	13.9

*Mr. L made 40 localizations daily for 22 days. All other *S*'s made 30 localizations daily. The same is true of Table 8.

TABLE 8

DIRECTION OF LOCALIZING ERRORS—ADULTS

ARM

Subject	Age	Sittings	Mean localizations per sitting Elbow	Wrist	Distal	Proximal
Mr. C	18	16	9.1	20.7	12.3	16.2
Mr. N	19	10	6.8	23.2	20.6	9.4
Miss R	20	6	7.3	22.6	20.0	10.0
Mr. M	20	8	19.4	10.6	20.7	9.2
Mr. L	23	32	5.5	24.4	12.2	17.7
Mrs. J	65	11	9.9	19.9	12.9	16.9
	Mean		9.6	20.2	16.4	13.2

TABLE 9*

LOCALIZATIONS ON HAND

Percentage of Total Localizations in Each Quadrant

	Direction ↑ Finger	↓ Wrist	← Distal	→ Proximal
Children	56	43	47	53
Adults	42	54	55	44

*Table 9 is read as follows: 56% of children's localizations on hand are toward the fingers, and 43% toward the wrist. Forty-two percent of adult localizations were fingerward, and 54% wristward, etc.

TABLE 10

LOCALIZATIONS ON FOREARM

Percentage of Total Localizations in Each Quadrant

	Direction ↓ Elbow	↑ Wrist	← Distal	→ Proximal
Children	36	63	58	42
Adults	32	68	55	44

We may conveniently summarize the frequency of localization in the various quadrants by the two groups in terms of the percentage of the total localizations recorded in each of the quadrants. The two tables, 9 and 10, present these percentages.

The reader should bear in mind that each point localized falls into two classifications of the above tables, since a point is located either in front of, or back of, the transverse meridian on the hand and so is classed as "toward the fingers" or "toward the wrist." Like-

wise it is either distal or proximal to the longitudinal meridian. For the volar forearm the designations "elbow" and "wrist" are similarly used to indicate the directions from the meridian.

If the reader will draw four small squares representing the hand and arm areas for adult and child subjects and indicate the appropriate directional designations and then write opposite each the values of the means from Tables 5, 6, 7, and 8, he will note an interesting contrast. This is also evident from the percentage tables, 9 and 10. On the average, adults localizing on the hand make errors more frequently toward the wrist than toward the fingers, in the proportion, wrist—18.0, to fingers—13.1, whereas the opposite is the case with the children, who localize more frequently toward the fingers than toward the wrist in the proportion, fingers—17.1, to wrist—13.1. Distal-proximal relations are reversed, it will also be noted, in the case of the hand—children localizing more frequently in the proximal and the adults in the distal direction. The contrast here seems all the more striking when we compare the forearms of the two groups. Here on the arm the trends seem to be strikingly identical for both groups.

If we consider the arcs of pronation of the sweep of the localizing hand as relatively the same, proportional to the sizes of hands, arms, visual angle, etc., it appears that the *children undershoot the mark and adults overshoot it.* The logical thing in such a case is to look to the important difference in the relative *timing* of the movements as the principal source of such difference. If we knew the critical frequencies for muscle contraction, or tetanus points, for the two groups and could then equate the two groups in these terms, we should be in a position to answer more definitely questions regarding the time factor in the accuracy and direction of the errors. Such an inquiry should be made but could not be undertaken in the experiments reported here. However, to expect that timing of the movements holds the key to this difference is hardly more than a gratuitous guess in view of the fact that every precaution was taken to see that all the movements were made at as nearly a uniform speed as possible. Since we have no comparative measure of speed in the two groups we are not in a position to say how they compare in the gross in this respect.

Discussion. The results of this investigation seem to point unambiguously to valid differences in the accuracy and direction of

localization between adults and children. Do children really localize more accurately than adults? Our *figures* carry the affirmative answer. But should this be taken as argument against the theory that localizations are orienting habits and that therefore adults should localize more accurately, being the more practiced?

Two counter objections may be presented: (1) There are many cases in which extended practice leads to extinction or partial extinction of a habit, e.g., in mechanisms of the conditioned reflex type. Again we may cite those cases, like the various picture completion tests, in which the adult performs less well than young children, possibly because he sees too many relations. To many inferences are, under certain conditions, not good for "insight." Either of these two conditions may lead to the same status as that found in this study without necessarily invalidating the essential learned character of the localizing response. (2) An attempt may be made to formulate an answer to the above question along lines suggested earlier in this paper. The evolution of the cortex is held by some anatomists and neurologists (e.g., Wilder, *History of the Human Body;* Herrick, *Brains of Rats and Men*) to follow the evolution of distance receptors. Gaining distance receptors introduces the possibility of temporal "delay" in response, and during this interim other things may transpire. The cortex as a vast compound shunt system mediates these other things. Coordinated or conditioned movements are cortically mediated, otherwise they do not take place.

Early infancy is essentially a thalamic period. Up to a certain age no "conditioned" types of learning take place (Peiper, *Hirntätigkeit des Saüglings*). The change from infancy to adulthood is marked by a period of myelinization covering approximately the first 16 years. During this time there is probably a progressive replacement of contact excitatory mechanisms by those functionally served by the distance receptors, e.g., ocular dominance. Children therefore probably depend chiefly upon tactual and kinaesthetic signals for localizing upon the skin, while adults depend upon vision as the distance-receptor substitute for localizing and distance discriminations.

In our experiments both the children and the adults made the localizations while blindfolded. Under such a condition we should expect that we have handicapped the adult to such an extent as to greatly diminish, at least temporarily, the accuracy of his local-

izing, by taking away the dominant visual "control" of the localizing movement. On the other hand, we have placed no such obstacle in the way of the children. It is even possible that blindfolding them may somewhat enhance their tactual and kinaesthetic discrimination.

If these conditions obtain, no *uncorrected* comparison of the relative accuracy of localizing by the two groups is justifiable. Further, theoretical deductions from an assumed real difference as a function of age cannot be legitimately introduced in support of any particular theory of the genesis of perceptions of haptic space. Real differences between the age groups, if they exist, must be demonstrated and quantified by a method which places both groups of subjects upon the same discriminal level. Any purely statistical solution to the problem, it would seem, can never properly take care of the objection of incomparability of the prime data raised above.

Experiment to Test the Foregoing Theory. At the writer's suggestion the following experiment was made by Mr. Robert J. Wherry and Mr. J. C. Newlin. Two adult men, aged 28 and 58 years, and two boys, aged 12, were used as subjects. In this experiment the hand alone was used, with two methods of localization: (1) the tactual-kinaesthetic method employed in the previous work reported in this paper; (2) a purely visual method. The subject's hand rested upon his knee throughout the experiment. Immediately after stimulation *S* opened his eyes and fixated the cross-section square printed upon the back of the hand. *S* then called out to *E* the coordinates of the spot localized as the stimulated spot. Five localizations were made using Method 1, then five using Method 2, and so on, until all the localizations for the sitting were completed.

Table 11 presents the distribution of the errors of localization in millimeters for each of the two methods for the four *S*'s. Table 12 presents the means and standard deviations. No attempt was made in this experiment to deal with comparative directions of localization.

A comparison of the means shows that the two 12-year-old boys localize more accurately by the tactual-kinaesthetic (*T-K*) method, and the two men more accurately by the visual method. The standard deviations for the men are approximately the same for both methods, being slightly larger for the method in which they show the greater error (*T-K*). In the case of the boys, the sigmas differ more markedly, the smaller sigma being associated with the method (*T-K*) which is the more accurate for them.

TABLE 11

DISTRIBUTION OF ERRORS IN MILLIMETERS

Tactual-Kinaesthetic *vs.* Visual Localization—Hand Only

	Adults				Children			
	Mr. J. C. N Age 28		Mr. W Age 58		D. B. Boy–Age 12		R. S. Boy–Age 12	
Error (m. m.)	*T-K*	*V*	*T-K*	*V*	*T-K*	*V*	*T-K*	*V*
0		5		3			1	1
1		1					1	2
2	1	3		2	5	3	2	4
3	1	7	1	3	3	4	2	5
4	1	2	1	3	4		3	2
5	2	2	2	1	3	4	4	1
6	3	4	1	1	3	2	3	4
7	5	11	3	3	4	5	8	2
8	2	2	1	1	4	4	6	2
9	4	3	1	4	8	2	4	3
10	5	2	4	1	4	3	4	4
11	3	4		1	2	4	3	1
12	6	2	1		2	7	5	6
13	4		4		3	1	3	3
14	4		1		3	1		1
15	1	2	1	1	1	4		3
16	3		2					
17	3		2	1	1			5
18						1	1	
19	1					1		
20						3		1
21						1		
22								
23	1							
N	50	50	25	25	50	50	50	50
Mean	10.86	6.16	9.4	6.16	7.98	9.92	7.82	8.90

TABLE 12

COMPARISON OF MEANS AND STANDARD DEVIATIONS

Adults *vs.* Children—Both Methods

	Means		Sigmas	
	T-K	*V*	*T-K*	*V*
Children	7.90	9.41	3.74	5.22
Adults	10.37	6.16	4.16	4.00

Suppose we compute the reliabilities of the differences shown amongst methods and age groups. If we employ the conventional formula for the reliability of a difference and compute the ratios of the differences to the root mean square errors (sigma) of the differences, we obtain the following values for the ratios: (1) In the

case of the boys, the ratio between the means of the *T-K* and visual methods is 0.235. The chances are therefore 59 in 100 that the difference is a valid one. The difference itself is 19.2% greater accuracy for the *T-K* method. (2) For the men, the ratio for the difference in the two methods is 0.728 in favor of the visual method. The chances are 77 in 100 that the difference is a valid one. The mean T-K error for the men exceeds the visual mean by 68.3% of the visual mean. This seems to verify the theory advanced above. The virtual equivalence in the case of the 10-year-old boys, and the significant difference in the values for the men, indicates a receptor differentiation allied with increased age.

(3) The ratio for the difference between the visual method in the two groups is 0.493, giving 69 chances in 100 that the difference in favor of the men is a valid one; while (4) the difference for the *T-K* method favors the boys, with a ratio of 0.441, or 67 chances in 100. Note that these ratios are of about equal certainty in cases (3) and (4) above.

Suppose now we compare the poorest sense mode of each group with the poorest of the other. This would be equivalent to handicapping both groups about equally, and therefore reducing both to approximately a comparable discriminal level. In this case (5) we merely compare the difference between the adult *T-K* and the children's visual means. The ratio of this difference to its sigma is 0.014. The chances are 50 in 100 of its being a true difference. When we place both groups upon an approximate discriminal level there is zero likelihood that there is a true difference. In so far as this treatment of the data is sound, the preceding statement may be regarded as confirming our theory.

Similarly if we compare (6) the differences between the best methods for each group, *T-K* for the boys and visual for the men, the ratio is 0.318, or 62 chances in 100 that the difference is a true one. Although not exceptionally large this case indicates the trend. Had we used still younger children, i.e., children below the inflection point for the two methods, the confirmation of our theory would have been all the more striking.

A further investigation is now in progress in our laboratory extending the methods described in this paper to wider age groups, with more subjects, increased number of sittings for the observation of the extent of relative practice effects, etc.

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LES ERREURS DE LA LOCALISATION CUTANÉE ET L'EFFET DE L'EXERCICE SUR LE MOUVEMENT DE LOCALISATION CHEZ LES ENFANTS ET LES ADULTES

(Résumé)

On compare les grandeurs et les directions des erreurs de localisation pour les stimulations punctiformes sur 30 superficies chacune d'un millimètre carré sur le dos de la main et la partie palmaire de l'avant-bras. Quatre enfants âgés de 10 ans et 7 adultes ont été les sujets dans les premières expériences. Ils ont fait trente localisations par jour pendant 7 à 32 jours. En opposition aux résultats de Ponzo et de Franz, on a observé des décroissances significatives des erreurs avec l'exercice sans connaissance. Les enfants ont été très supérieurs aux adultes dans la localisation selon une méthode tactile-kinesthésique. Les deux groupes ont travaillé les yeux bandés. On a observé aussi des différences significatives dans la direction des erreurs.

On offre la théorie que la différence observée entre les groupes ne s'explique pas par la différence d'âge mais par le fait que les groupes ne sont pas réduits au même niveau de discrimination. Si la dominance visuelle vient avec le progrès de l'âge, les adultes ont trop de désavantages quand les yeux sont bandés. Pour mettre cette théorie à l'épreuve on a fait une autre expérience avec deux groupes différant en âge pour comparer une méthode seulement visuelle avec une méthode tactile-kinesthésique. Ici les adultes ont été vraiment supérieurs dans la méthode visuelle et inférieurs dans la méthode T-K.

L'article met en question les divers déductions de telles données offertes comme preuves contre les théories dites "d'expérience" du développement de la perception de l'espace haptique. Douze tables et une figure.

Renshaw

ÜBER DIE IRRTÜMER DER HAUTLOKALISATION UND DIE WIRKUNG DER ÜBUNG AUF DIE LOKALISIERENDE BEWEGUNG BEI KINDERN UND ERWACHSENEN

(Referat)

Man vergleicht die Grösse und Richtung der Irrtümer in der Lokalisierung bei Punktreiz, auf Feldern von 30 Quadratmillimeter auf dem Handrücken und dem untern Teile des Vorderarms. Vier Kinder von 10 Jahren und 7 Erwachsene dienten in den ersten Experimenten als Vpn. Während 7 bis 32 Tagen machte man täglich 30 Lokalisationen. Im Gegensatz zu den Ergebnissen von Ponzo und Franz, fand man eine bedeutsame Abnahme der Irrtümer nach Übung ohne Wissen. Die Kinder waren den Erwachsenen im Lokalisieren mit der kinaesthetischen Tastmethode entschieden überlegen. Beiden Gruppen wurden während des Experiments die Augen verbunden. Man beobachtete auch bedeutsame Unterschiede in der Richtung der Irrtümer.

Man stellt die Möglichkeit hin, dass die zwischen den Altersgruppen beobachteten Unterschiede falsch sind, und nur dem Umstande zu verdanken sind, dass die Gruppen nicht auf einem gleichen Niveau stehen und daher eigentlich nicht vergleichbar sind. Wenn eine Überlegenheit des Sehens sich mit zunehmendem Alter entwickelt, so behindert das Verbinden der Augen den Erwachsenen in ungebührlicher Weise. Um diese Theorie zu prüfen machte man noch ein Experiment mit zwei Altersgruppen, wobei man eine kinaesthetische Tastmethode mit einer Methode des reinen Sehens verglich. Dabei erwiesen sich die Erwachsenen in der Letztern entschieden überlegen, in der kinaesthetischen Tastmethode jedoch standen sie den Kindern nach.

Der Verfasser zieht die verschiedenen Schlussfolgerungen von solchen Ergebnissen, die man als Argumente gegen die "Erfahrungstheorien" von der Entwicklung der Wahrnehmung der Haptic aufstellt, in Zweifel. Zwölf Tafeln und eine Abbildung.

RENSHAW

CUTANEOUS LOCALIZATION IN CONGENITALLY BLIND VERSUS SEEING CHILDREN AND ADULTS*

From the Psychological Laboratories of the Ohio State University

SAMUEL RENSHAW, R. J. WHERRY, AND J. C. NEWLIN

THE PROBLEM

This paper may be regarded as Part II of a previous paper reporting studies comparing the accuracy of the localizing movement with seeing children and adults (1). Using a tactual-kinaesthetic method in both groups, and localizing on back of hand and volar forearm, the children proved to be significantly more accurate in localizing than did the adults. In a further experiment the adults proved superior to the children when a purely visual method of localizing was employed. Blindfolding was found to be a disproportionate handicap to the adult subjects. Based upon these findings a theory was proposed that dependence upon contact excitation for localizing in childhood becomes replaced by distance receptor function at some age possibly not far from puberty.

Tactual-kinaesthetic localization is highly accurate in childhood and poor in adulthood; purely visual localization is poor in childhood and approaches maximum accuracy in adulthood. If, therefore, we wish to throw into contrast the transition from contact to ocular dominance, in the localizing movement, we may do so by examining the process of localizing punctate stimulations upon similar skin areas made by congenitally blind subjects of comparable ages. To report such experiments is the object of the present paper.

In the congenitally blind there is no possibility of visual surrogation. If it could be shown that congenitally blind adults localize in a fashion comparable to that of seeing children, who are superior to seeing adults in *T-K* localization, we should have additional confirmation of our theory of ocular dominance. And since there are demonstrably significant practice effects in all cases we should also furnish evidence favoring the "experience" theory of the genesis of perception (of haptic space) which has been attacked so vigorously by the Gestalt writers.

*Recommended by Albert P. Weiss and received for publication by Carl Murchison of the Editorial Board, August 29, 1929.

The blind adult must use the same localizing process which he used in his childhood. The seeing adult, on the other hand, has been shown to replace contact and movement-produced cues with visual or visual-linguistic ones from about the age of puberty.

If the foregoing assumptions are sound we should also find that congenitally blind children, having had relatively little *T-K* training in localizing, should be similar in the accuracy of localizing to the seeing adults whose *T-K* localizing movements have now suffered a considerable decrement because of the shift to dependency upon vision as the principal or dominant sensory "control."

If either or neither of these cases is found to hold, the problem remains open. The experiments described in this paper were made to determine these points.

Method

Through the courtesy of the Director, Mr. Lum, and the Principal, Mr. Palmer, we were able to use seven blind children and four blind adults as subjects from the Ohio State School for the Blind, at Columbus. The children ranged from 8 to 14 years, with the average age 11½. The adults were 20, 21, 22, and 24 years. The sexes were about equally represented. All were congenitally blind save two, who had been blind since about two years of age. Sittings were arranged for alternate days over a period of 16 days. Two areas were used, one on the back of the non-preferential hand and one on the volar forearm midway between wrist and elbow. The areas were 30 millimeters square. The *T-K* method employed has been described in full in the previous paper (1). From 30 to 50 localizations were made at each sitting by each subject. In the following section we present the data from our experiments with the blind, together with a summary of results obtained upon the seeing children and adults of the previous experiments for comparison.

Results

The following tables and figures give complete confirmation to both cases cited above. The blind children are similar to the seeing adults, and the blind adults are similar to the seeing children. The critical ratios are of such magnitudes as to carry practically complete certainty as to the trustworthiness of the differences. All four groups show decided practice effects.

This table shows that the four adult blind subjects made 1080

TABLE 1

CUTANEOUS LOCALIZATION: BACK OF HAND OF BLIND ADULTS—MEAN DAILY ERROR IN MILLIMETERS

Subject	Age	Days 1	2	3	4	5	6	7	8
Mr. L.	21	6.96	5.77	4.50	4.87	4.23	4.40	4.27	3.83
Mr. G.	22	9.88	7.47	6.83	7.60	7.80	7.80	7.67	6.87
Miss K.	20	6.52	4.37	4.27	4.80	4.00	4.00	4.00	3.47
Miss W.	24	7.98	6.00	4.57	4.13	4.83	5.30	4.67	4.57
Means		7.84	5.90	5.04	5.35	5.21	5.38	5.15	4.70
S.D.		4.189	3.581	2.840	2.729	2.786	2.959	2.804	2.892
$S.D._{I.}$		1.294	1.100	1.038	1.331	1.523	1.477	1.473	1.321
$S.D._{M.}$		.2962	.3269	.2593	.2499	.2543	.2701	.2560	.2722
Number of localizations		200	120	120	120	120	120	120	120

localizations on the back of the hand in 8 sittings. The table is read as follows: The mean error in millimeters on the first day, for the four *S*'s, was 7.84, the standard deviation of the distribution of the errors of all *S*'s on this day was 4.189, and the mean sigma of the individuals was 1.294, while the sigma of the mean error for the group was of the order 0.2962, etc.

TABLE 2

CUTANEOUS LOCALIZATION: FOREARM OF ADULT BLIND—MEAN DAILY ERROR IN MILLIMETERS

Subject	Age	Days 1	2	3	4	5	6	7	8
Mr. L.	21	8.05	7.47	6.27	6.73	5.90	5.63	5.90	5.83
Mr. G.	22	12.08	9.73	8.57	7.30	7.73	6.23	6.23	7.47
Miss K.	20	10.06	8.03	6.5	6.70	6.10	6.70	4.87	4.77
Miss W.	24	8.54	5.60	6.03	5.93	5.13	5.10	3.60	3.70
Means		9.68	7.71	6.84	6.66	6.21	5.92	5.15	5.44
S.D.		5.566	4.482	3.790	3.292	3.119	3.055	2.868	3.128
$S.D._{I.}$		1.570	1.474	1.012	.4871	.9467	.6043	1.026	1.392
$S.D._{M.}$		.3946	.4091	.3460	.3005	.2847	.2789	.2618	.2856
Number of localizations		200	120	120	120	120	120	120	120

This table presents the figures for the blind adult group localizing upon the volar forearm. It is read as the previous table.

Tables 3 and 4 show the corresponding figures for the blind children localizing upon the back of the hand and volar forearm. The tables are to be read as was Table 1.

TABLE 3

CUTANEOUS LOCALIZATION: BACK OF HAND OF BLIND CHILDREN—MEAN DAILY ERROR IN MILLIMETERS

Subject	Age	Days 1	2	3	4	5	6	7	8
Mr. W.	8	8.48	9.70	8.90	8.74	6.60	6.93	5.03	5.30
Mr. R.	11	12.20	10.92	13.24	11.90	12.50	11.10	12.83	12.33
Mr. C.	14	9.48	10.08	8.60	8.83	8.50	7.50	6.00	4.70
Miss G.	14	7.98	7.98	6.92	5.78	7.00	5.20	3.93	3.60
Miss J.	9	10.48	9.86	8 06	10.82	9.25	10.90	8.53	9.23
Miss M.	11	11.56	12.36	9.68	8.46	9.83	8.53	8.93	6.6
Miss P.	14	11.82	9.60	10.54	10.54	9.60	11.50	8.60	7.60
Means		10.29	10.07	9.42	9.17	9.05	8.81	7.69	7.05
S.D.		5.437	5.228	4.766	4.766	4.598	4.403	5.064	4.865
$S.D._{I.}$		1.554	1.238	1.888	1.783	1.833	2.243	2.766	2.768
$S.D._{M.}$		.2906	.2794	.2548	.2629	.3173	.3038	.3494	.3357
Number of localizations		350	350	350	330	210	210	210	210

TABLE 4

CUTANEOUS LOCALIZATION: FOREARM OF BLIND CHILDREN—MEAN DAILY ERROR IN MILLIMETERS

Subject	Age	Days 1	2	3	4	5	6	7	8
Mr. W.	8	9.60	13.11	11.30	10.00	13.90	10.17	8.27	9.00
Mr. R.	11	16.72	16.34	21.24	13.90	17.90	18.43	21.57	17.13
Mr. C.	14	15.26	14.80	12.78	13.03	11.70	10.63	8.33	7.00
Miss G.	14	10.96	11.86	11.94	12.30	10.20	8.96	9.63	6.33
Miss J.	9	14.22	15.66	11.06	11.46	13.57	13.20	11.57	10.30
Miss M.	11	17.02	15.14	12.52	14.16	9.73	12.10	12.90	7.30
Miss P.	14	15 86	14.60	12.34	12.34	13.30	13.70	10.73	10.33
Means		14.23	14.50	13.35	12.45	12.90	12.76	11.86	9.63
S.D.		7.775	6.758	7.422	6.298	7.186	6.652	6.984	6.277
$S.D._{I.}$		2.668	1.421	3.392	1.408	2.546	2.896	4.260	3.386
$S.D._{M.}$		.4156	.3612	.3967	.3467	.4959	.4590	.4819	.4332
Number of localizations		350	350	350	350	210	210	210	210

Tables 5 and 6 present a résumé of the results obtained in the case of the seeing children and adults. We print here only the means, standard deviations of the means by days, and standard deviations of the individuals, for the purposes of comparison. The tables of the original figures for these subjects are printed in full in the previous article.

Figure 1 presents a graphic comparison of the means for the various blind and seeing subjects. If the reader will note in the tables the small sizes of the various standard deviations of these

TABLE 5

CUTANEOUS LOCALIZATION: DAILY MEAN OF GROUP, SIGMA OF THE INDIVIDUAL, AND THE SIGMA OF THE MEAN

Seeing Children

Hand

Means	1	2	3	4	5	6	7
Days	10.4	5.5	5.1	4.2	3.5	3.4	2.6
$S.D._{I.}$	1.594	2.105	1.779	1.995	1.500	1.312	1.393
$S.D._{M.}$	.797	1.053	.889	.998	.750	.656	.697

Volar Arm

Means	1	2	3	4	5	6	7
Days	7.8	4.3	4.7	4.8	3.6	3.6	3.0
$S.D._{I.}$	1.776	1.704	1.672	1.687	1.590	1.221	1.037
$S.D._{M.}$	.888	.852	.836	.844	.795	.611	.519

TABLE 6

CUTANEOUS LOCALIZATION: DAILY MEAN OF GROUP, SIGMA OF THE INDIVIDUAL, AND THE SIGMA OF THE MEAN

Seeing Adults

Back of Hand

Days	1	2	3	4	5	6	7	8	9	10
Means	12.3	11.4	11.0	10.1	10.4	10.0	10.8	8.7	8.8	7.9
$S.D._{I.}$	4.144	2.871	3.750	2.407	2.681	2.698	2.724	1.504	2.170	1.363
$S.D._{M.}$	1.566	1.085	1.417	0.910	1.013	1.020	1.112	0.673	1.085	0.682

Volar Arm

Days	1	2	3	4	5	6	7	8
Means	15.1	15.00	14.7	14.6	15.1	14.5	13.1	11.8
$S.D._{I.}$	3.526	2.073	2.533	3.242	2.525	2.822	2.797	3.613
$S.D._{M.}$	1.439	0.846	1.034	1.324	1.031	1.152	1.251	1.807

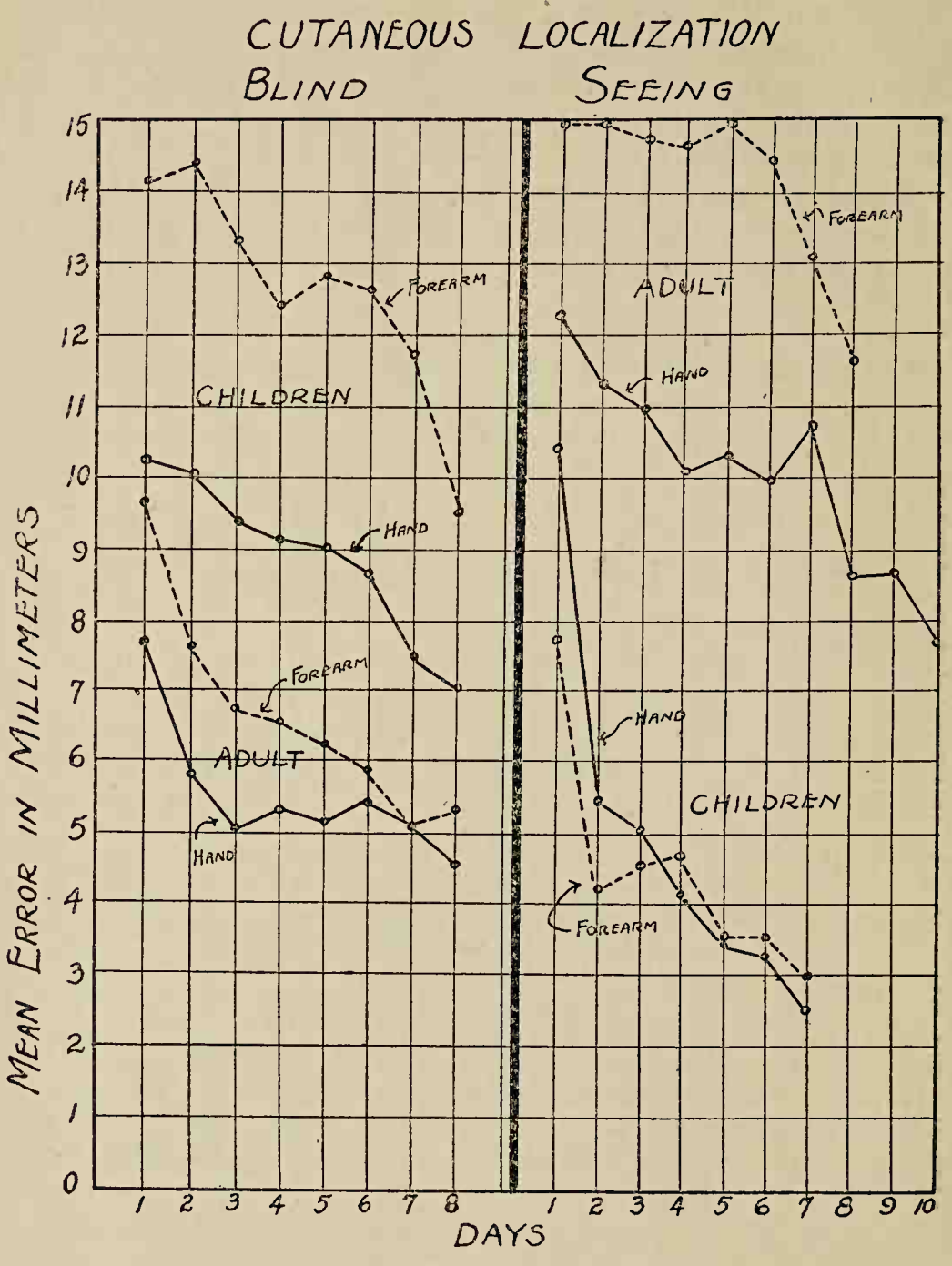
CUTANEOUS LOCALIZATION
BLIND
SEEING
MEAN ERROR IN MILLIMETERS
DAYS
CHILDREN
FOREARM
HAND
ADULT
FOREARM
HAND
ADULT
HAND
FOREARM
CHILDREN
HAND
FOREARM

FIGURE 1

means he will observe that lines drawn upon the figure to represent the limits of + and — one sigma would bound, in each case, a very narrow ribbon.

Table 7 shows the reliability of the differences (critical ratios) between the mean errors of localization on arm and hand for the four groups. The comparison of blind and seeing children here is of interest, since in seeing children there are but 64 chances in 100 that the hand and arm differ significantly. The practice curve of Figure 1 illustrates this, since these children localize *more* accurately on the forearm during the first three days, and slightly more accurately on the hand during all of the succeeding five days. In blind children of the same age, however, there is statistical certainty (critical ratio 7.27) favoring the superior accuracy on the hand, but withal *the blind children localize with significantly less accuracy* than the *blindfolded* seeing children! We conclude from this that vision must serve as an instructive or corrective agent in childhood localizings, and from the seeing-adult curves (Figure 1) we must conclude that vision almost completely comes to dominate the process in the adult life of the seeing.

TABLE 7

THE RELIABILITY OF DIFFERENCES BETWEEN ARM AND HAND

		Diff.	$\sigma_{diff.}$	$\frac{Diff.}{\sigma_{diff.}}$	Chances in 100
Children					
	Blind	3.77	0.5188	7.27	100
	Seeing	.41	1.131	0.36	64
Adults					
	Blind	.99	0.4209	2.35	99
	Seeing	4.10	1.994	2.06	98

This table is read as follows: The difference between the mean errors on arm and hand for blind children on all days is 3.77 mm. The sigma of this difference is 0.5188, and the ratio $\frac{diff.}{\sigma_{diff.}}$ is 7.27. This amounts to practical certainty, or 100 chances in 100, that the difference is a true difference, i.e., greater than zero.

Table 8 represents the critical ratios between blind and seeing; and Table 9 the same figures comparing adults and children These tables are read as Table 7 above.

TABLE 8

THE RELIABILITY OF DIFFERENCES BETWEEN BLIND AND SEEING

		Diff.	$\sigma_{diff.}$	$\frac{Diff.}{\sigma_{diff.}}$	Chances in 100
Children					
	Hand	3.99	.8860	4.50	100
	Arm	8.17	.8736	9.36	100
Adults					
	Hand	4.39	1.266	3.47	100
	Arm	7.50	1.595	4.70	100

TABLE 9

THE RELIABILITY OF DIFFERENCES BETWEEN ADULTS AND CHILDREN

		Diff.	$\sigma_{diff.}$	$\frac{Diff.}{\sigma_{diff.}}$	Chances in 100
Children					
	Hand	3.23	.4051	7.94	100
	Arm	6.01	.5312	11.31	100
Adults					
	Hand	5.15	1.491	3.45	100
	Arm	9.76	1.728	5.65	100

CONCLUSION

1) In localizing on the skin by the tactual-kinaesthetic method (*a*) blind adults are superior to blind children; (*b*) blind adults are superior to seeing adults; (*c*) seeing children are superior to seeing adults; and (*d*) seeing children are superior to blind children.

2) Localizing upon the skin is a coenotrope. Significant practice effects were observed in all groups of subjects.

3) Even though the initial accuracy on forearm is less than on hand, the forearm is brought well below the initial hand status after a small amount of practice. Hence any theory of immutable "local signs" on these skin areas must be false.

4) Initial accuracy on forearm is greater than on hand for seeing children. The reverse is true of all other groups.

5) Plotted on a scale of years, the blind adult curves for both arm and hand represent projections of the curves of the blind children. The blind adults' superiority over the blind children is therefore associated with the increased discrimination which comes from

more extended "practice." The inferiority of the seeing adult to the seeing child is obviously, therefore, due to the shift in method of localizing which comes with distance receptor dominance.

6) Blind adults are significantly superior to seeing adults. The blind adults make almost no noteworthy gains on the hand after the second day's practice, while the seeing adults gain rapidly in accuracy throughout the 10 days of their practice. This fact alone seems to lend weight to the theory of the coenotropic character of the visual control of the localizing movement in adulthood and of the difference in the genesis of haptic space in blind and seeing subjects. An equally striking contrast is to be noted in the case of the blind and seeing adult forearms. Here the blind diminish progressively in error with successive practice, throughout the eight sittings, but the seeing adults show no improvement for the first five days, then suddenly increase with great rapidity during the next three days.

7) Our results call into question conclusions regarding the teaching of the blind based upon experimentation upon blindfolded seeing adult subjects. In the light of these results we must conclude that it is unsafe to extend to the blind principles derived from studies on the seeing.

8) The results suggest, likewise, that in the education of the seeing children it is possible that a too early emphasis upon purely visual means of instruction is not likely to be as efficacious as instruction involving contact and kinaesthetic mechanisms.

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LA LOCALISATION CUTANÉE CHEZ LES ENFANTS ET LES ADULTES AVEUGLES-NÉS ET CEUX QUI VOIENT

(Résumé)

Dans un article antérieur on a présenté des expériences sur l'exactitude comparative des localisations faites sur deux superficies de la peau par des adultes et des enfants voyants. On a employé deux méthodes: (1) une méthode tactile-kinesthésique, et (2) une méthode simplement visuelle. Les enfants (âgés de 10 ans en moyenne) ont montré plus d'exactitude que les

adultes avec la méthode T-K, mais beaucoup moins avec la méthode visuelle.

Une comparaison de la meilleure méthode pour chaque groupe n'a montré nulle différence significative, résultat que l'on peut comparer avec le refus de la théorie "expérience" de perception par la Gestalt. On a proposé une théorie de changement de dominance du "contrôle" par contact au "contrôle" visuel du mouvement de localisation, pour expliquer ces résultats.

Pour donner plus de force à cette théorie, on présente ici les expériences sur des enfants et des adultes aveugles-nés. Les enfants aveugles correspondent en exactitude aux adultes voyants, et les enfants voyants aux adultes aveugles. Ce résultat s'accorde avec l'expectation en termes de la théorie de dominance oculaire. La localisation est considérée coenotropique, en opposition de la doctrine de Litze des signes locaux. Des effets significatifs de pratique ont été montrés chez tous les groupes des sujets, ce qui ne s'accorde pas avec les résultats de Ponzo et de Franz. On met en question les généralisations sur les aveugles basées sur les expériences avec les ʰultes voyants aux yeux bandés, et on considère la signification des résᵘ ᵗts comparatifs dans leurs rapports avec l'enseignement des enfants voy ts.

RENSHAW, WHEERY, ET NEWLSN

DIE HAUTLOKALISATION BLIND GEBORNER VERGLICHEN MIT DER SEHENDER KINDER UND ERWACHSENER

(Referat)

Wir berichteten früher über Experimente bezüglich die Lokalisation in zwei Hautstellen von sehenden Erwachsenen und Kindern. Es wurden zwei Methoden angewandt: (1) eine tast-kinaesthetische und (2) eine rein visuelle Methode. Die Kinder (Durchschnitt 10 jährig) waren nach der T-K Methode den Erwachsenen überlegen, aber nach der visuellen Methode geringfügig schwächer.

Der Vergleich der Ergebnisse der für jede Altersgruppe günstigsten Methode wies keine bemerkenswerte Unterschiede auf, ein Befund, der übereinstimmt mit der Gestaltpsychologie, die die "Erfahrungstheorie" der Wahrnehmung verneint. Man schlug als Theorie fürdie Erklärung dieser Ergebnisse vor, dass bei den Lokalisationsbewegungen die Vorherrschaft der Berührungsbestimmung in eine der viuellen übergehe.

In der gegenwärtigen Arbeit werden über Experimente berichtet die an blindgebornen Kindern und Erwachsnen vorgenommen wurden, und die die Annahme bestärken. Blinde Kinder entsprechen bezüglich der Genauigkeit den sehenden Erwachsenen, und sehende Kinder blinden Erwachsenen. Dieser Befund stimmt überein mit der Erwartung nach der Theorie der Augenvorherrschaft. Man nimmt an die Lokalisation sei coenotropisch, im Gegensatz zur Litze' schen Lehre von lokalen Zeichen. Bei allen Gruppen der Versuchspersonen zeigen sich bedeutende Wirkungen der Übung, im Gegensatz zu den Ergebnissen von Ponzo und Franz. Man stellt Verallgemeinerungen, die sich auf die Arbeit von sehenden Erwachsnen mit verbundenen Augen berufen, und die Bedeutung der vergleichenden Befunde mit Bezug auf die Erziehung sehender Kinder in Frage.

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